Distr.
LIMITED

UNIDO/IO.611
7 February 1985

ENGLISH

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

DEVELOPING A USED OIL RECYCLING ACTIVITY IN DEVELOPING COUNTRIES

General Considerations and Alternative Available Technologies *

Working Paper Series

No. 1

Prepared by

Division of Industrial Operations

---

* The designations employed and the presentation of material do not imply the expression of any opinion whatsoever on the part of the secretariat of the United Nations concerning the legal status of any country or its Authorities, or concerning the delimitations of its frontiers. This document has been reproduced without formal editing.

V.85-22094

TABLE OF CONTENTS

		Page
A.	Sustainable Development	2
B.	The Case of Used Oil Recycling	2
	1. Phase I - Prefeasibility	3
	a. Quantity and Quality Assessment of Generated Used Oils	3
	b. Collection System Assessment	4
	c. Alternative Used Oil Uses	4
	d. Marketing Assessment	5
	2. Phase II - Implementation	5
C.	Re-refining Technologies	8

Flow Charts

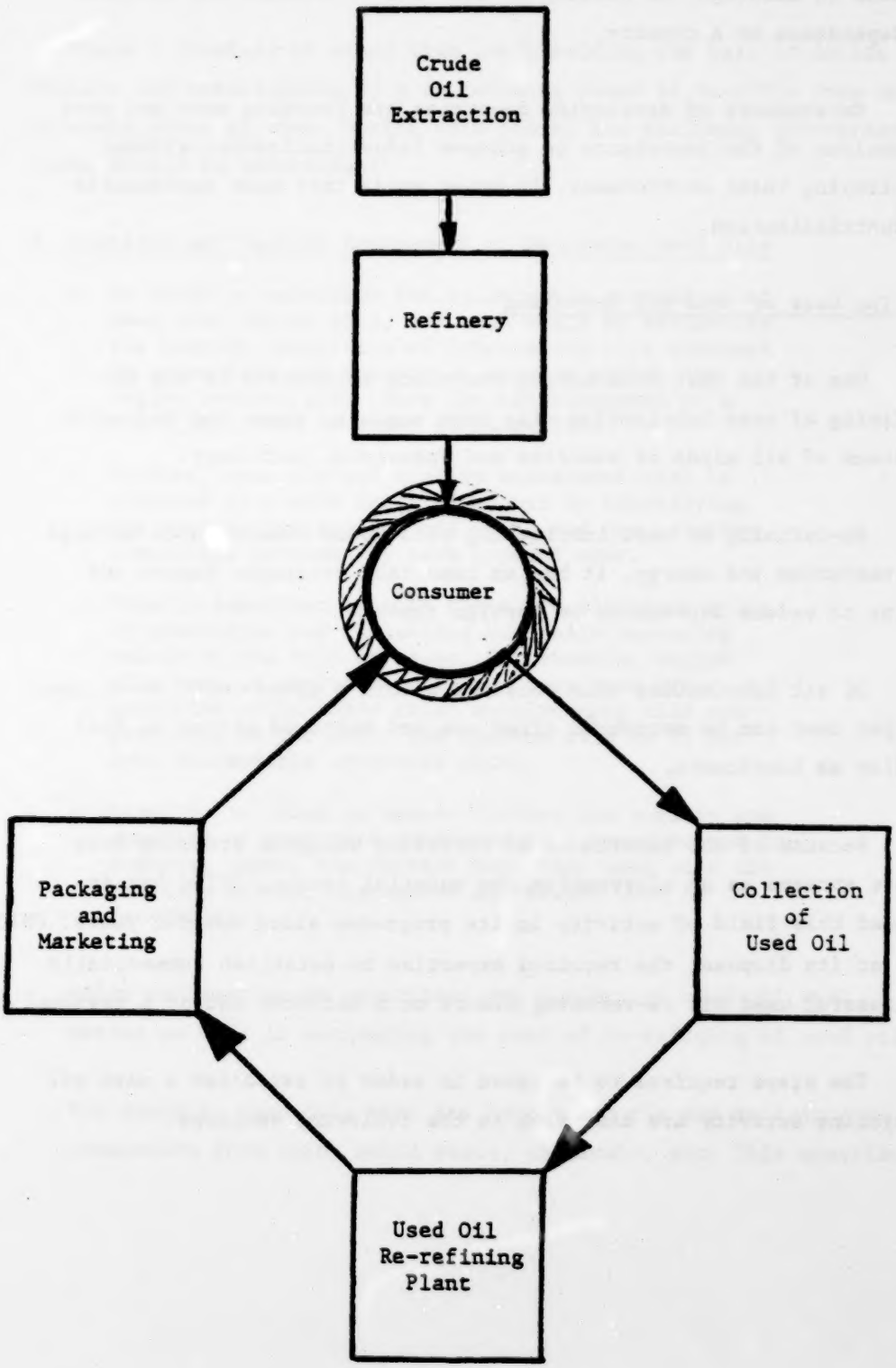
- Lubricating Oils/Used Oils/Recycled Oils Flow Chart, Flow Chart I, iii
- Alternative Processing Technologies for Lube Oil Re-refining, Flow Chart II, 10

Appendices

- Used Lube Oil Plant with a Capacity of 1,000, 2,000, 3,500 tpa of Dewatered black Oil: Hydrotreating-Distillation Process/ Appendix I 14
- Abstract from Preinvestment Study; Waste Lube Oil Refining Project in the Gulf Region/Acid-Clay Process/ Appendix II 17
- Information Sources on Re-refining Processes and Economics/ Appendix III 23

FLOW CHART I

Lubricating Oils/Used Oils/Recycled Oils Flow Chart



A. Sustainable Development

Environmental protection and recycling are today an important factor to maintain the quality of life and to enhance the economic independence of a country.

Governments of developing countries are becoming more and more conscious of the importance to achieve industrialization without destroying their environment. In other words they want sustainable industrialization.

B. The Case of Used Oil Recycling

One of the most interesting recycling activities is the re-refining of used lubricating oils from engines, gears and hydraulic systems of all kinds of vehicles and industrial machinery.

Re-refining of used lubricating oils means considerable savings of resources and energy, it has an important strategic impact and helps to reduce dependency on foreign imports.

Of all lubricating oils consumed within a given country, at least 50 per cent can be recovered after use and recycled either as fuel and/or as lubricants.

Because of the importance of recycling valuable products from waste streams as an alternative raw material source, UNIDO has included this field of activity in its programme since several years. UNIDO has at its disposal the required expertise to establish commercially successful used oil re-refining plants on a national and/or a regional level.

The steps required to be taken in order to establish a used oil recycling activity are discussed in the following sections:

1. Phase I - Prefeasibility

Assessing Whether a Used Oil Recycling Plant is a Feasible Economic Activity

Phase I consists of steps that are providing the base to decide whether the establishing of a re-refining plant is feasible from an economic point of view. During this phase, the following activities/ tasks should be undertaken:

a. Quantity and Quality Assessment of Generated Used Oils

- o In order to determine the collectable quantities of used lubricating oils, one must begin by estimating the overall quantities of lubricating oils consumed by automotive and industrial sources within the region/country/area where the establishment of a recycling plant is under consideration.

- o Further, quantity and quality assessment will be achieved in a more detailed manner by identifying the type of lubricating oil users and the relative quantities consumed by each type of user.

  This is important because there are different rates of generating and collecting used oils depending mainly on the type of usage. For example, engine oils have an approximate 63 per cent used oil potential collectable rate; metalworking oils and gear oils 80 per cent; and turbine oils an 87 per cent collectable potential rate.

- o Finally, in order to assess further the quality and quantity of used oils generated by automotive and industrial users, the current ways that used oils are handled, stored, aggregated and reused must be determined.

Above information on quantities and quality of used oil will assist as well in estimating the cost of re-refining of used oils.

For example, used oils that are handled poorly may sustain contamination from rain, solid waste, chemicals, etc. This contributes

to lower the quality of used oils and to require a more elaborate and expensive process to clean it. Moreover, extensive post-usage contamination affects the base oil yield - a fact that diminishes the economic attractiveness of a used oil recycling activity.

b. Collection System Assessment

A second and major part of the pre-feasibility phase is to determine whether there is a collection system for used oils and if not what possibilities exist to develop an efficient collection system based on the following information:

- location of sources using lubricating oils and generating used oil;
- quantities of used oils generated by individual sources;
- proposed location of used oil recycling plant.

c. Alternative Used Oil Uses

A third important pre-feasibility step is to assess the competing uses (if any) of used oils and through which channels these used oils are reaching alternative ways of reuse.

For example, used oils can be used directly as fuel and as dust suppressors on country/unpaved roads, etc. Both of these uses have serious environmental adverse effects. When used oils (especially automotive used oils) are burned as fuel without pre-cleaning, a range of metals (principally lead) is released in the atmosphere. These metals are dangerous to health. If the used oil contains gasoline or other flammable material when it is burned it may present risk of fire or explosion. Used oil applied as a dust suppressor is also dangerous to health. It may contaminate ground water sources and/or adjoining water bodies and fields.

Another competing use of used oils is reprocessing/recycling into fuels and/or lubricants. Recycling may itself generate environmental problems but these problems are controllable and newer technologies are low in pollution and their by-products are often marketable.

d. Marketing Assessment

A final but equally important step in the pre-feasibility phase is the assessment of potential local and/or export markets for recycled re-refined products.

This marketing information will enable prospective entrepreneurs to decide whether they want to produce fuel and/or lubricating oils. This decision is important because on it depends the type of technology they should utilize.

Once steps (a) through (b) are being completed, prospective entrepreneurs and/or governments are ready to proceed - if obtained information warrants the establishment of a used oil recycling activity - with Phase II.

2. Phase II - Implementation

Establishing an Integrated Used Oil Recycling System

During Phase II entrepreneurs and/or governments should proceed with the following activities/actions:

a. To determine the location and size of the plant based on information on the location of used oils generating sources and the quantities of generated used oils.

b. To develop and organize an efficient used oil collection system.

In designing a used oil collection system the following facts should be taken into consideration:

- o The efficient collection of used oil is the main pilar in the successful operation of a used oil recycling plant.
- o Used oil generating sources are dispersed.
- o Quantities of used oils generated by individual sources may be relatively small.
- o The used oil collector should have the appropriate incentives/constraints in order to bring the collected used oil to the used oil re-refining plant.

c. To devise a regulatory/incentives system that will achieve the channeling of used oil resources to desired intermediate and end-uses.

d. To estimate investment and production costs.

e. To select the type of technology to be used in recycling used oils. This decision will be based on the information available on the type of used oils collected, level and type of contamination sustained, storage, transportation, the estimated yield and the type of desired end-product. Further, technology choice will be based on the available alternatives in neutralizing, treating, disposing and/or reusing waste products generated during the recycling process.

f. To organize training courses for technical personnel of recycling used oil plants. This activity should be undertaken in co-operation with the technology transferring (if any) enterprise and/or organization.

g. To organize a marketing system for re-refined products.

These objectives and activities should be guided by available state-of-the-art surveys on used oils/recycled oils integrated systems as have been implemented in several industrial countries and some developing countries. These countries have substantial experience in recycling their used oils and their experience can be useful not only in selecting cost-effective, environmentally acceptable technologies, but in devising effective collection and regulatory frameworks. The final aim of a used oil recycling project should be to develop information based on the experience obtained in an individual country/region/plant in order to gradually develop more general guidelines that would be particularly relevant to the conditions prevailing in developing countries.

Finally, the public should be educated in order to obtain voluntary compliance in handling and disposing used oils in environmentally sound ways.

Although all implementation stages of a used oil re-refining activity are important and merit lengthier discussion, we will deal here only with some additional aspects related to the re-refining technologies.

C. Re-refining Technologies

The main treatment technologies for used lubricating oils are processing used oils into fuels and/or to re-refine them into base lubricating oils.

The burning of used oils as fuel is by far the predominant use worldwide in comparison with the re-refining into lubricants. This can be explained because of the relatively high heating value of used lubricating oils which promotes its utilization as fuel.

Furthermore, the processing of used oils as fuel requires considerably less investment than the one required for the conversion of used oils into lubricants.

In spite of these facts, several governments in both industrial and industrializing countries encourage the promotion of re-refining by devising appropriate regulatory systems and several of them by subsidizing the establishment of re-refining plants.

The promotion of used oil re-refining plants worldwide is primarily based on the following facts:

- From 1 ton of used oil, 0.6 to 0.8 tons of base lubricating stocks adequate for lubricant production are obtained. In contrast, 0.2 tons are produced from the same quantity of crude oil.
- The re-refining of used lubricating oils enables the repeated use of these oils.
- The trade balance is improved through supplementing lubricating oil imports with recycled lubricating oils.
- The burning of used lube oil contributes very little to supplement demand for energy sources due to the fact that the share of energy recoverable from spent lubricants is approximately 0.5 per cent compared to the world energy demand. 1)

---

1) Dr. H. Joidl, Austroplan

Retrospectively, when thinking of used lubricating oil-refining, not only profitability should be considered, but also environmental aspects and national economic issues such as foreign exchange savings and the preservation of resources. Recycling of used oils into lubricants is an economically attractive, environmentally sound alternative to burning as fuel.

From re-refined lubricating oil base stocks several kinds of oils can be derived when blended with the appropriate additives, such as:

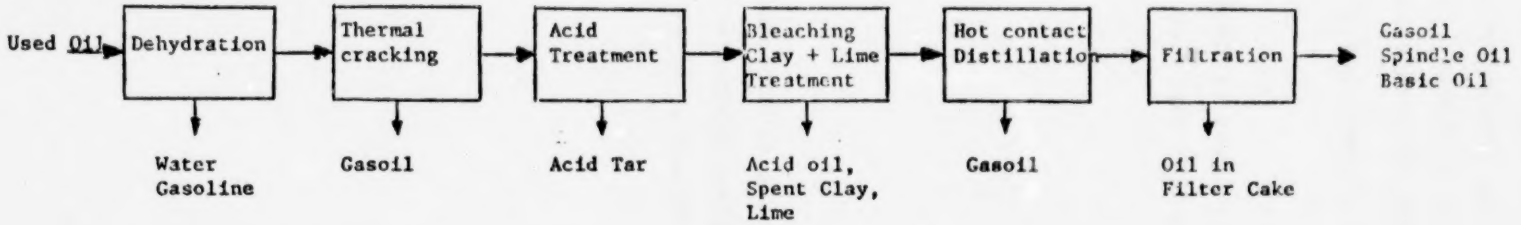
- o single and/or multigrade motor oils
- o hydraulic oils
- o gear oils
- o cutting dilutants
- o greases, etc.

There are a number of used oil processing/re-refining technologies. We are presenting here a number of these technologies which are known to be efficient both from an economic and an environmental point of view.

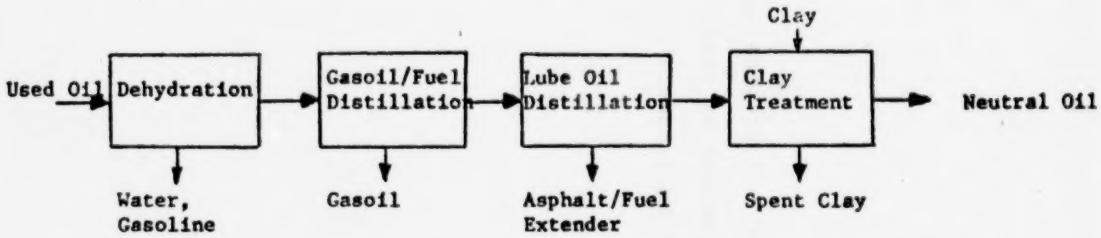
FLOW CHART II

a. ALTERNATIVE PROCESSING TECHNOLOGIES FOR LUBE OIL RE-REFINING (Meinken Process/Austroplan,
Luwa Process/Gesellschaft für Umweltschutz)

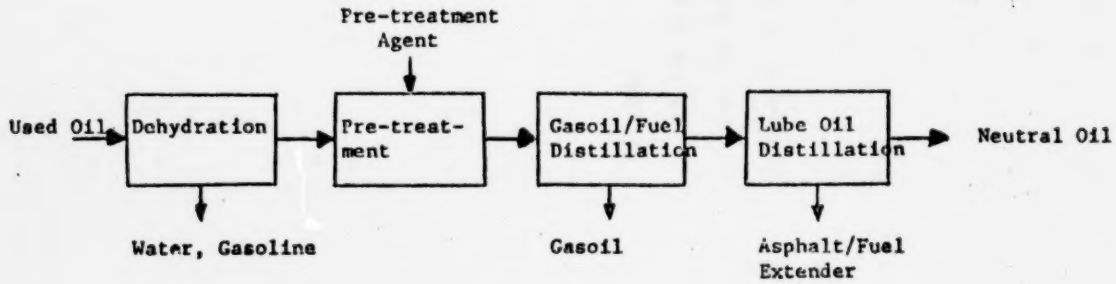
1. Acid Clay Re-refining



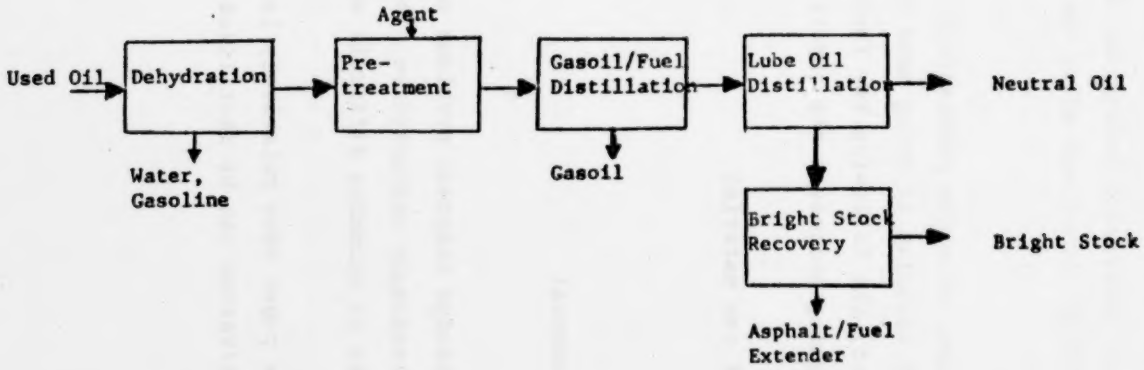
2. Thin-Film Vacuum Distillation Combined with
Conventional Clay Finishing without Acid Treatment



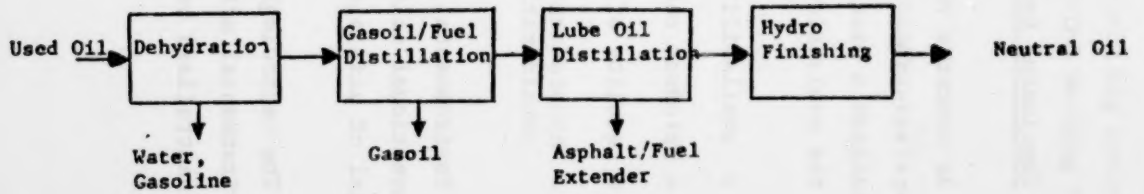
3. Total Evaporation - Evaporation of
Lube Compounds under High Vacuum



4. Total Evaporation Process with Bright Stock Recovery



5. Thin-Films Vacuum Distillation Combined with Hydrofinishing After-treatment



b. Other Available Technologies

- o Solvent extraction

  The central treatment consists of extraction of lube compounds with propane.

- o Chemical treatment (other than acid re-refining)

  The central treatment consists of precipitation of metals containing compounds with diammonium phosphate.

c. Concluding Remarks

As concerns the Technology selection, once the prefeasibility steps/assessments are completed and a decision is being made to establish a used oil re-refining plant, the following key factors in the evaluation of used oil re-refining processes are important:

- o availability and flexibility of raw material
- o product recovery yield
- o quality of used oil feedstock
- o by-products, wastes and environmental considerations/constraints

Environmental considerations and sludge disposal problems make conventional acid/clay processes increasingly unattractive. The disposal of acid sludge and clay residues is becoming difficult and costly.

The technologies described in this paper have relatively lesser environmental effects and by-products/wastes can be reutilized and/or neutralized before disposal.

UNIDO can assist in selecting the proper technology and provide the required technical expertise, organize the training of local managers, scientific/technical personnel as well as semi-skilled personnel.

As concern the organization of an efficient collection system, marketing assessment and marketing strategies for recycled/re-refined products, the development of an appropriate regulatory machinery and incentives, as well as a public information system, are necessary parts of an integrated successful used oil recycling/re-refining activity and are to be dealt with in forthcoming separate UNIDO Working Papers

Used Lube Oil Plant with a Capacity of 1000, 2000 and 3500 tpa of Dewatered Black Oil Hydrotreating-Distillation Process *

Process Yield and Utility Consumption

Assumption: Used oil feed composition containing 10% water and low boilers and 15% Gasoil

Product	Feed Compos. % wt	Recovery rate % wt	Yield % wt	Production per year t		
Used oil	110	-	-	1100	2200	3850
Water/gasoline	10	-	-	100	200	350
Dewatered black oil	100	-	-	1000	2000	3500
Gasoil/Fuel	15	14.8	99	148	296	518
Neutral oil	79	76.5	97	765	1530	2680
Asphalt/fuel extend.	5.7	7.0	-	70	140	245
Light ends	0.3	1.7	-	17	34	57
Formulated lube oil (with 12% additives)				860	1720	3000

Utilities Consumption (approx. values)		Consumption per ton recovered product
Fuel consumption	: kg	18
Cooling water	: (35°C)m^3	2
Pretreatment agent	: kg	40
Electric power	: kWh	64
Electric power installed: kWh		95

* Source: Dr. R. Movahedi, Gesellschaft für Umweltschutz

1. MANUFACTURING COST PER TON RECOVERED PRODUCT

(estimation, not binding in any case. Units taken should be checked with local conditions). The costs stated are relating to metric tons and based on actual plant data experience.

1.1. Fixed cost		Plant capacity (tpa)		
		1000	2000	3500
- personnel (3 shift operation, tot. 12 persons at US $ 4000.- p.a. each		48.-	24.-	14.-
- depreciation (5 yrs payback) - maintenance (3% of investment) - clear space requirements ($10/m^2 yr)		128.-	113.-	65.-
Subtotal		276.-	137.-	79.-

1.2. Utilities	US $/ton			
- Fuel is produced in plant	-			
- Electricity (64 kWh/t at $ 0.05/kWh	3.5			
- Water (2m^3/t at $0.25/m^3	0.5			
Subtotal	4.0	4.-	4.-	4.-

1.3. Raw material and by-products				
- Used oil (purchase and transport)	50.-			
- Pretreatment agent (ca. 5% wt added)	8.-			
Subtotal	58.-	58.-	58.-	58.-
TOTAL MANUFACTURING COST FOR NEUTRAL OIL		338.-	199.-	141.-
Optional				
- Additives for blending	105.-			
- Cans/drums for packing	100.-			
Subtotal	205.-	205.-	205.-	205.-
GRAND TOTAL		543.-	404.-	346.-
2. Wholesale price		1250.-	1250.-	1250.-
3. Gross margin		707.-	846.-	904.-

Remarks

Aforementioned figures are based on European price standards, during Spring 1984 and are subject to review at local conditions. Administration, management, taxes and distribution costs are not included.

Abstract from Preinvestment Study
Waste Lube Oil Refining Project in the Gulf Region
Acid-Clay Process *

The Mass Balance as the Base of Production Cost Calculations

This mass balance is based on the results of the laboratory analyses. Of course the actual mass balance will depend very strongly on the actual waste lube oil composition and can vary in certain limits.

Nevertheless the assumed consumption values can be expected to be average values during operation. All percentage indications are in mass %:

A	Waste lube oil input:	3000.0 t/a
	Bottom sediments + water:	4.0 %
B	Waste lube oil without water and bottom sediments:	2880.0 t/a
	H_2SO_4 consumption (8% of B):	230.0 t/a
C	Acid oil (90% of B):	2592,0 t/a
	Bleaching clay consumption (5% of C):	129.6 t/a
D	Sum of products (83% of B):	2390.4 t/a
E	Product mix of waste lube oil re-fining	
	Base oil 80% of D:	1912.4 t/a
	Spindle oil 8% of D:	191.2 t/a
	Gasoil 12% of D:	286.8 t/a
		2390.4 t/a

* Source: Dr. H. Joidl, Austroplan

Blending of products

Production of monograde oil in 200 l-drums:

1,711.2 t/a base oil mixed with 80 kg performance package base oil:

	1,721.2 t/a	base oil
	137.7 t/a	performance package
TOTAL	1,858.9 t/a	Monograde oil filled in 200-l drums (180 kg product drum)

Number of 200-l drums: 10,328 drums

Production of multigrade oil filled in 4-cans:

191.2 t/a base oil + 191.2 t/a spindle oil mixed with 90 kg performance package/t base oil + spindle oil and with 130 kg viscosity improver/t base oil + spindle oil:

191.2 t/a	base oil
191.2 t/a	spindle oil
34.4 t/a	performance package
49.7 t/a	viscosity improver
466.5 t/a	multigrade oil filled in 4 l-cans (3.6 kg product/can)

Number of 4-l cans: 129,584 cans

Survey of Material Cost for Base Lube Stock and Finished Lube Oil Production

Base: 3,000 t/a waste lube oil
1-shift operation, 2000 net production hours/year
Mass balance according to ANNEX I

Chemicals	Cost Calculation	Annual Cost Dhs/a
Sulfuric acid (650 Dhs/t/H_2SO_4) specific consumption 77 kg/t waste lube oil	650 x 0.077 x 3000	150,150
Bleaching clay (FF80 : 1700 Dhs/t) specific consumption 43 kg/t waste lube oil	1700 x 0.043 x 3000	219,300
Lime (200 Dhs/t) specific consumption 3 + 80 kg/t waste lube oil	200 x 0.083 x 3000	49,800
Ammoniak (2,500 Dhs/t) specific consumption 8 kg/t waste lube oil	2500 x 0.088 x 3000	60,000
Water chemicals Specific cost 20 Dhs/t waste lube oil		
	TOTAL CHEMICALS	539,250

Chemicals	Cost Calculation	Annual Cost Dhs/a
Auxiliary materials		
Filter paper (specific air weight of paper: 70 g/m^2, 6 Dhs/kg) specific consumption 30 m^2/day x 250 d/a = 30 x 250 x 0.07 x 6		3,150
	TOTAL AUXILIARY MATERIALS	3,150
Power and utilities		
Electric power (0.075 Dhs/kWh) specific consumption 100 kWh/t waste lube oil	100 x 0.075 x 3000	22,500
Water (6.5 Dhs/m^3) specific consumption	2.67 x 6.5 x 3000	52,065
Diesel oil (4.2 Dhs/gal corresp. to 1.1 Dhs/kg) could be provided by own production 133 kg/t waste lube oil	0.3 x 133 x 1.1 x 3000	131,670
Waste water discharged water is clean due to pruification equipment provided		
	TOTAL POWER AND UTILITIES	206,235
Total material cost for base lube stock production		748,635

Chemicals	Cost Calculation	Annual Cost Dhs/a
Additives for finishing base lube stocks		
According to ANNEX 1 the following yearly amounts of performance packages and viscosity improvers are needed:		
172,100 kg performance package à 5 Dhs/kg:		860,500
49,700 kg viscosity improver à 40 Dhs/kg:		198,800
TOTAL ADDITIVES		1,059,300
Total material cost for finished products production		1,807,935

Production Costs versus Sales Revenues

Annual input: 3,000 t/a waste lube oils

Cost item		Annual operating cost (Dhs/a)
Personnel		1,519,800
Waste lube oil supply		800,000
Total materials for finished products production		1,807,935
Products marketing		1,284,736
TOTAL OPERATING COST		5,412,471
CAPITAL COST		2,112,000
TOTAL PRODUCTION COST		7,624,471
SALES REVENUES		
Selling Price / 4 l-can (multigrade oil and monograde oil):	25 Dhs	
Selling Price / 200 l-drum (monograde oil):	900 Dhs	
Sales Revenues for Multigrade Oils		
129,584 cans/a x 25 Dhs / can:		3,239,600
Sales Revenues for Monograde Oils		
10,328 drums 10 x 900 Dhs/drum		9,295,200
TOTAL SALES REVENUES		12,534,800
GROSS PROFIT		4,910,329

Information Sources on Re-refining Processes and Economics

UNIDO is in contact with several consultants and companies around the world which have expertise in re-refining used oil. We have received material from the following companies/experts:

- Austroplan, Austria
- Gesellschaft für Umweltschutz, Austria
- Jolar Associates, USA
- Luwa Process, Switzerland
- Meinken Process, FRG
- Recon Systems, Inc., USA
- Dr. W. Irwin, USA
- National Bureau of Standards, USA
- American Petroleum Institute (API), USA

For further information please contact:
S.P. Maltezou
Industrial Development Officer
Environment, Pulp and Paper and Basic
Chemicals Unit/Chemical Industries Branch
Division of Industrial Operations, UNIDO
P.O. Box 300
A-1400 Vienna